Smart Sensor with Gesture Detection for Lighting Control Applications

Harish Raman, Lilly Huang

Lighting & Control Business Group, Leviton

Background

Occupancy detection with Passive Infrared Sensor (PIR) is state-of-art today for smart lighting control applications. Basically, when the PIR detects the movement of human body, it sends out a signal which triggers light on/Off.

There are some drawbacks with PIR occupancy detection. A PIR sensing could not provide any further information relating to movement of a human body. For example, is a person going into a room or is the person jumping up or down? Similarly, in terms of adjusting the lighting control operation (e.g., dimming or brightening of a light), a PIR sensor typically cannot discriminate between different types of movement a person may make. Therefore, if a person wants to adjust performance of lighting, the person must manually touch a button or a switch/dimmer bar to enable dimming variation, light color tuning or any other advance features.

An image sensor is occasionally used for security purposes rather than lighting control. Drawbacks, such as privacy concerns and higher costs, have prevented its broad adoption to the lighting control industry.

Gesture detection, in general, has been applied in many areas such as automotive, healthcare, and virtual reality. Due to its complexity and expensive design, gesture detection has not been used today for a simple lighting sensing and control application.

A novel solution of Smart Sensor with gesture detection for Lighting & Control application

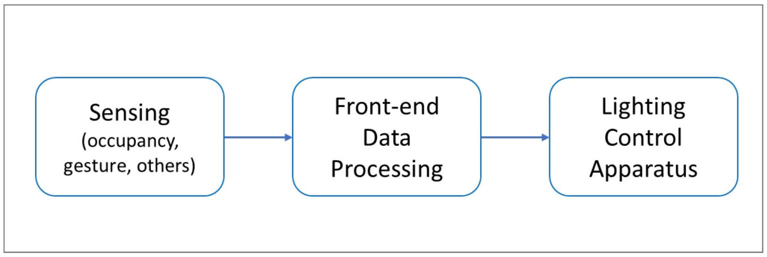
Here, we introduce a novel gesture detection mechanism for smart lighting control. It could be designed with on-shelf high volume manufacture (HVM) components (low cost). A simple gesture detection scheme is proposed to enable a feature uniquely suitable to lighting applications. A Smart Lighting Sensor could take a full control of its operations with human gestures. All of these can be accomplished in a touchless manner, which is even more critical due to hygiene concerns under COVID-19. Such a gesture detection scheme can be implemented by integrating with a traditional occupancy detection sensor such as PIR sensor. This leads to a cost advantage in HVM production. It also provides the ease of use for an end-user.

© 2022 Leviton Manufacturing Co., Inc.

1. Concept of Smart Lighting Sensor with Gesture Detection

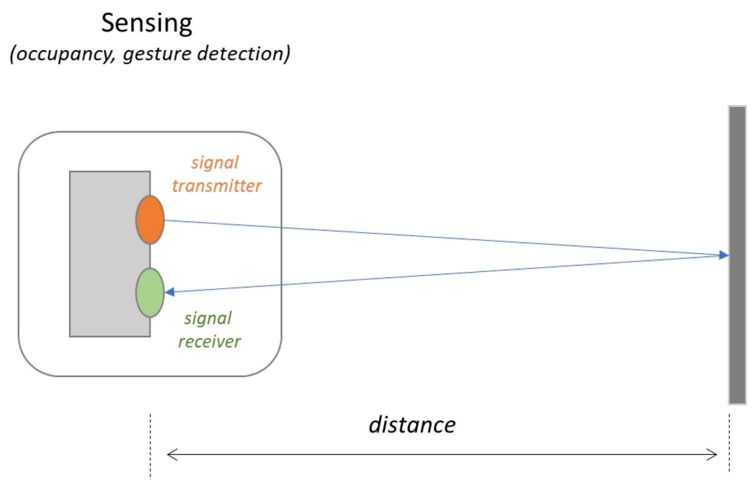
A conventional occupancy sensing with a passive infrared sensor (PIR) is used to monitor the change of heat emitted by a human body. As the variation of heat is detected due to the body movement, this indicates the occupancy of a person in a certain space. The field-of-view (FOV) of the PIR sensor may not be achievable or may be somewhat limited due to an insufficient thermal disturbance appearing on the PIR sensor. For example, when a person is out of direct sight of view from the PIR sensor (e.g., sit at office blocked by cubic wall) or if a person's movement is not large or fast enough (e.g., typing on CPU keyboard), the PIR sensor may not be triggered. In addition, such a PIR sensor cannot recognize "*how*" a person moves.

The Smart Lighting Sensor with Gesture Detection consists of three basic functional blocks as follows:


Sensing
(occupancy, gesture, others)
Front-end Data Processing
Lighting Control Apparatus

The principle of Smart Lighting Sensor with Gesture Detection is fundamentally different from occupancy detection with PIR sensing. Such a smart sensor operates in a manner called as Time-of-Flight (ToF), which detects not only human occupancy but also the "characteristic" of human movement, for example, one's moving direction or travel trajectory.

Basically, the sensing unit consists of two elements, signal transmitter and signal receiver. Motion of a human body can be detected with a pair of transmitted and received signals. The relative distance between a sensor and a subject (human) can be derived based on the time duration of signal travel (e.g., ToF).



In practice, there are multiple pairs of transmitted and received signals emitted by a single sensor. Therefore, the relevant information on an object in 3D space could be obtained.

Depending on the type of signal applied in a ToF implementation, the sensor could be referenced to infrared vertical-cavity surface-emitting laser (IR VCSEL), ultrasonic or radio frequency (RF) radar. There is a two-element (one pair of transmitted/ received signals) sensor from multiple vendors in the market today. In addition, sensors with four or more -elements are currently in development.

The functional block of “Front-end Data Processing” is by its definition to perform basic data collection and simple post-data manipulation. And it stores the related information in a local register or memory. Then, it outputs data stream on a standard wire I/O interface (e.g., I^2C) or via a wireless protocol to a computer host such as a microprocessor.
The data stream updates “dynamically” and instantly, representing both the position and direction about the movement of a human gesture.

To reduce cost and simplify the design, an integrated sensor with both a sensing component and a “Front-end Data Processing” unit on a single IC package can be designed.

The “Control Apparatus” is the “brain” to make a decision for an action. Such an action can be switching a relay or adjusting light dimming or tuning other performance. Typically, the apparatus consists of a microcontroller, power converter, relay, and other relevant analog and digital circuits.

2. Principle & Operation of the Smart Lighting Sensor with Gesture Detection

As discussed in the previous section, the Smart Lighting Sensor with Gesture Detection can provide information on both the position and movement of human in a space. Such information can be utilized as well as customized to a Lighting Control application.

- **Sensing with Gesture Detection**

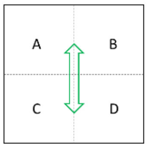
With a multi-element ToF sensor, different hand movements or human gestures can be distinguished using different sensing elements to detect movements/gestures in different areas/zones of space. Besides the relative position in a space, the direction of movement and the trajectory of a "trip" can be recognized and captured. Such information can be processed, and then, used to control light operations.

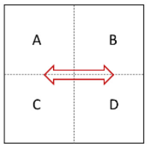
Here are a couple of examples for illustration. However, this disclosure should not be limited to the cases provided below.

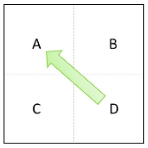
A.) Four-zone Sensing with Gesture Detection

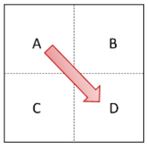
As illustrated below, a sensor with four-zone detection could identify the relative movement across different locations, indicated as A, B, C and D. As a person makes a hand gesture according to a pre-defined pattern, the person can control light performance without physically touching a device.

- Light Switch - ON = Move a hand up-down-up vertically
- Light Switch - OFF = Move a hand left-right-left horizontally
- Light Dimming - Increase = Move a hand from bottom to top diagonally
- Light Dimming - Decrease = Move a hand from top to bottom diagonally


light switch - ON


light switch - OFF


light dimming - Increase

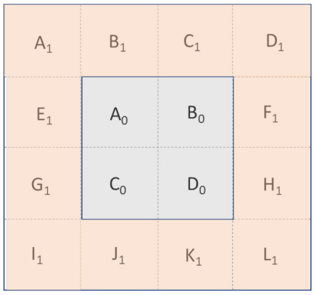

light dimming - decrease

B.) Sixteen-zone Sensing with Gesture Detection

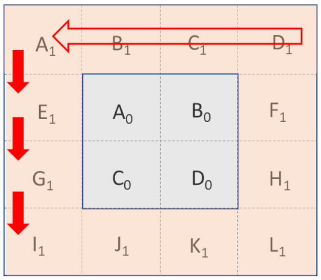
With more granularity of a sensor with gesture detection, more advanced features could be supported.

The drawing below represents sensing zones divided into four-by-four blocks. Such an arrangement could be utilized and support multiple modes of operations.

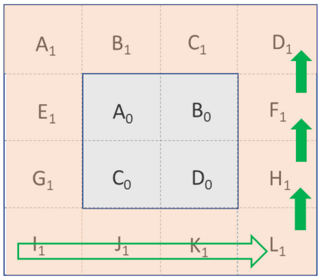
For example, the central two-by-two block (A_0, B_0, C_0, D_0) can serve as a basic set of product features as defined in the section “A” above. Then, the remainder of the divided sensing zones (A_1 … L_1) can be utilized to enable a more advanced function.



Here shows one of these applications to control light dimming on a granular level.


Light dimming-down

10% - 30% - 50%


Light dimming-up

20% - 50% - 80%

- Light dimming-down.
  - Move a hand from right to left (D_1 -> A_1) to signal the operation request for light “dimming-down”
  - Move a hand down with 1-step (A_1 -> E_1) to enable 10% reduction in brightness
  - Move a hand down with 2-step (A_1 -> G_1) to enable 30% reduction in brightness
  - Move a hand down with 3-step (A_1 - > I_1) to enable 50% reduction in brightness

- Light dimming-up.
  - Move a hand from left to right (I_1 -> L_1) to signal the operation request for light “dimming-up”
  - Move a hand up with 1-step (L_1 -> H_1) to enable 20% increase in brightness
  - Move a hand up with 2-step (L_1 -> F_1) to enable 50% increase in brightness

    - Move a hand up with 3-step (L_1 -> D_1) to enable 80% increase in brightness

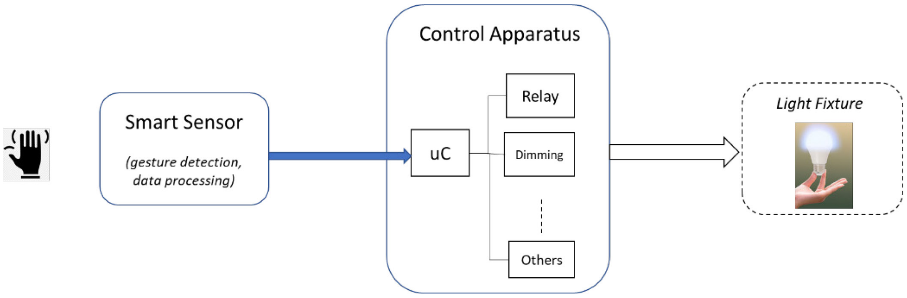
C.) 3D Sensing with Gesture Detection

To fully take advantage of Smart Sensor with Human Gesture, one can also consider its sensing effect on a third dimension in space. For example, a person comes closer or moves away from a reference point.

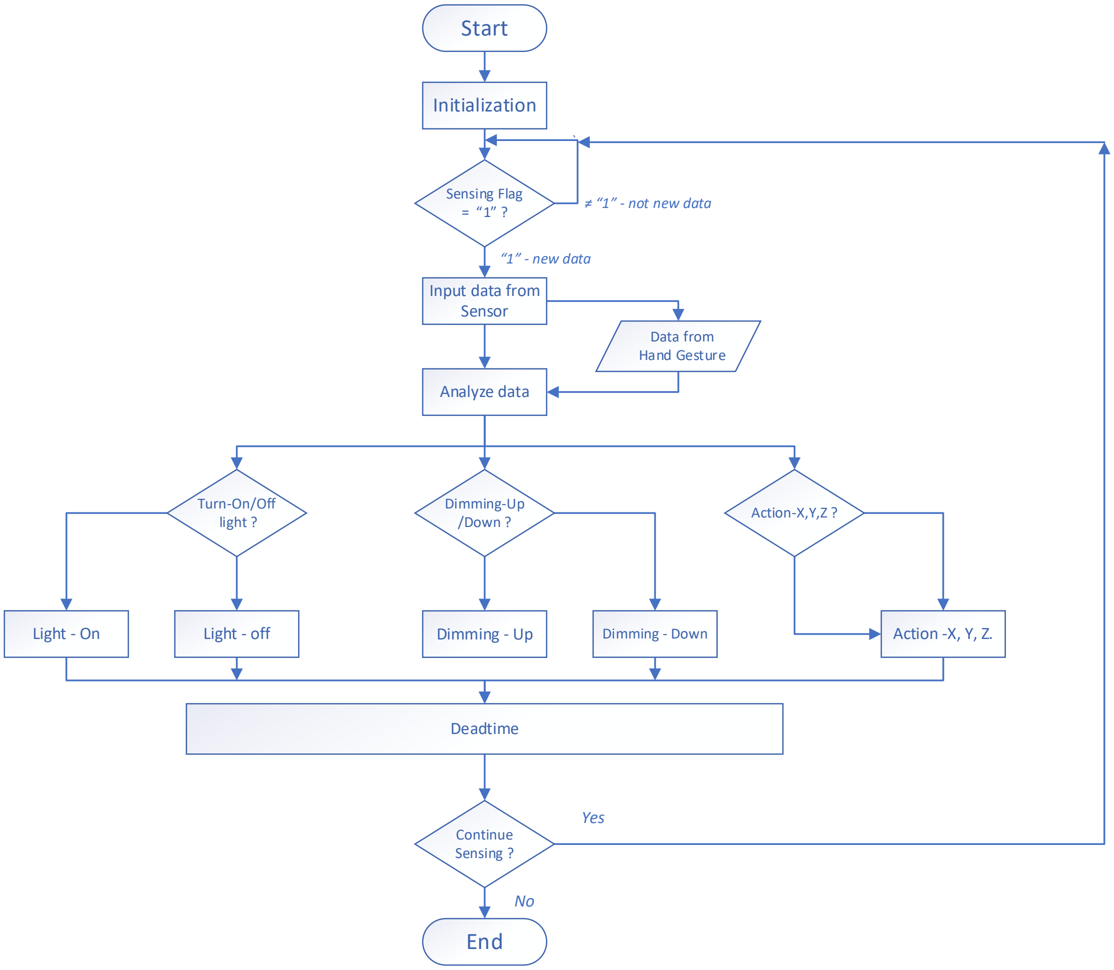
For example, when a person goes out of an office (across an entry door), the light would turn off accordingly. Another application would be people-counting. By sensing a person's movement and direction, we would know how many people move in and out of a space (e.g., an office in a building).

- **Lighting Control Application with Smart Sensor with Human Gesture**

As discussed above, the Smart Sensor with Human Gesture could respond to a gesture by a user to control the performance of lighting. Based on the sensing information, the lighting control apparatus would process the sensing data and issue an action request accordingly. For example, in the case A.) discussed above, the user gesture signals a request of "Light-On" with hand moving up-down-up vertically. Then, the control unit would output corresponding commands to switch a relay to turn on the light.



The flowchart below illustrates a procedure on how the operation takes place:



Summary

This disclosure introduces a novel lighting control scheme with hand gesture operation and provides the next level intelligence of light control. In addition, this disclosure facilitates a flexible and friendly interface between a device and an end user. Not only can a light be switched ON and OFF based on occupancy, but also the lighting performance, such as dimming up/down or color tuning, can be adjusted with user's hands or the body movement without physically touching a control device. This would be even more beneficial due to hygiene concerns of the current COVID-19 pandemic environment.

Reference

https://www.st.com/en/imaging-and-photonics-solutions/time-of-flight-sensors.html

https://invensense.tdk.com/products/ch101/